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ABSTRACT

A study examined the extent to which common knowledge structures and the presence of common performance components are important factors in reasoning. The eye fixations of 37 college students were recorded as they solved four types of complex inductive reasoning tasks: (1) verbal analogies, (2) figural analogies, (3) verbal series completions, and (4) figural series completions. Results showed that item-type manipulations resulted in significant differences in information processing, reflecting the role of common knowledge structures in reasoning task performance. (FL)

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Eye Movement Analysis of Task and Content Commonalities in Information Processing

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Abstract

The experiment reported herein was designed to test the premise that similarities in knowledge stores and in the particular performance components involved in item solution are major factors resulting in unities in inductive reasoning across task forms. The eye fixations of 37 college students were recorded as they solved complex inductive reasoning items of four types: (a) verbal analogies, (b) figural analogies, (c) verbal series completions, and (d) figural series completions. Item-type manipulations resulted in significant differences in information processing, reflecting the role of common knowledge structures in reasoning-task performance.

Eye Movement Analysis of Task and Content Commonalities in Inductive Reasoning

Identification of similarities in performance across tests of intellectual processes has been of considerable interest to psychologists over the past decade, as evidenced by the large number of factor analytic investigations of cognitive tests and test batteries. Problems of inducing structure have been of widespread interest in this regard. Traditional psychometric approaches held such problems to be particularly good measures of general intelligence, evidenced by the consistently significant correlations between different task forms, such as analogies, series completions, and classifications, and across different task contents, such as verbal and figural items (Cattell, 1971; Horn, 1968).

Information-processing psychologists have been interested in problems of inducing structure because it is believed that the mental processes underlying successful task solution are basic to human cognition (Pellegrino & Glaser, 1980). In contrast to the psychometric assumption of a general intelligence factor (i.e., the existence of a unitary phenomenon) as the basis of the significant correlations across task forms and contents, information-processing psychologists (Greeno, 1978; Pellegrino & Goldman, 1983; Sternberg, 1980) have suggested that such correlations result from commonalities in information processing across different induction tasks.

Interest now is growing in identification of sources of these commonalities. For example, similarities in performance (however measured) for a set of items may be the result of common knowledge structures, or common performance components for items in the set. The work reported herein is designed to test the premise that knowledge structures and similarities in constituent performance components both are central factors underlying similarities in performance for different tests of inductive reasoning.

With respect to advancing theory in the study of aptitude processes, Snow (1979) points out the fruitfulness of identifying four forms or levels of process differences.

Differences may be seen in (a) the particular components or processing steps used in item solution, (b) the sequence in which these steps are executed, (c) optimal strategy components, such as double checking, (d) and gross differences in the program systems used by different subjects. The work of Sternberg (see 1980b,) and Pellegrino and others (e.g., Pellegrino & Glaser, 1982; Pellegrino & Goldman, 1983) has provided information regarding the duration and sequential distribution of processing stages during various tests of inductive reasoning. This work utilized estimates of component latencies taken from subtasks or partial tasks.

A different though complementary approach to elucidation of the different levels of process differences is to record eye fixations during solution of intact tasks. Dillon (Note 1), and Dillon and Stevenson-Hicks (Note 2) provide eye movement data relevant to processing during different information-processing stages. Eye scan information regarding the sequential ordering of processing steps is provided in Dillon & Stevenson-Hicks (Note 2, Note 3). Eye movement considerations of strategy differences have been undertaken (Bethell-Fox, Lohman, & Snow, Note 4; Snow, 1978). In addition to considering gross strategy differences between subjects, Dillon & Stevenson-Hicks (Note 2) identified gross differences in performance <u>within</u> <u>subjects</u> (i.e., over trials).

Unities in reasoning may be studied at the various levels delineated by Snow (1979), using (a) latency or accuracy measures recorded from subtasks, partial tasks, or intact tasks, or (b) eye movement recording. Using the former approach, Sternberg and Gardner (1983), identified significant commonalities in total item <u>and</u> component latencies, resulting from content and item-type manipulations. Content manipulations are believed to have their effect due to differences in invoked knowledge stores, while differences in item type pertain to the particular performance components involved in item solution.

No reported attempts have been made to use eye movement data to test the premise

that similarities in (a) knowledge structures and in (b) particular performance components involved in item solution are major factors resulting in unities in inductive reasoning across item types and items varying in content. Moreover, the investigation reported herein extends previous work by using complex figural analogies in which the entire data set is considered (i.e., correct and incorrect trials).

Method

Subjects

The sample consisted of 37 undergraduate students enrolled in an introductory educational psychology class. All participants had normal vision uncorrected or normal vision corrected by hard contact lenses. Males and females were approximately equally represented.

Stimuli

Sixteen items were taken from Level H-Grade 11+ of the Cognitive Abilities Test (Thorndike & Hagen, 1974). The items were chosen to sample the difficulty range within Level H. Four of each of the following types of items were selected: (a) verbal analogies, (b) figural analogies, (c) verbal classifications, and (d) figural classifications. Each item was reproduced individually on a 35mm slide for presentation. For both types of analogies, the task format was:

$$A_1 \rightarrow A_2 : A_3 \rightarrow \boxed{C}$$

$$D_1 \; D_2 \; D_3 \; D_4 \; D_5$$

For the two types of classification items the task format was:

$$A_1 \; A_2 \; A_3 \; A_4 \; \boxed{C}$$

$$D_1 \; D_2 \; D_3 \; D_4 \; D_5$$

Subjects were tested individually. Test items were presented to a subject on a rear-screen projector at a viewing distance of 57cm. Eye fixations were monitored with a Whittaker oculometer system, Model 1992. The pupil-centered corneal reflectance option provides horizontal and vertical coordinates at 60Hz. Following a brief calibration procedure a subject was instructed to fixate a point at the center of the screen, in preparation for item presentation. A trial was terminated when a subject

reported the chosen response option.

Results

The data were analyzed to determine the effects of item content and item type on scanning. The eye movement indices used in this experiment are defined in Table 1.

Insert Table 1 about here

Indices were selected from among a larger set used in our work (see Dillon & Stevenson-Hicks, Note 2, Note 3; Dillon & Wisher, 1981) on the basis of specific considerations. We sought to disentangle visual attendance requirements from cognitive processing phenomena.

Two approaches seemed viable in this regard. One approach would be to construct items (from different item types) having equal numbers of elements or points corresponding to each problem-solving stage, thereby equating items with respect to visual attendance. We chose not to construct our own items, as we were interested in using item sets with known psychometric properties. In particular, we were concerned that the four item sets be equivalent in difficulty level.

The approach we took was to select eye movement indices that were not tied to the number of item elements located in specific portions of the problem array. Indices selected tap the sequential distribution of processing steps, rather than the relative allocation of processing resources (i.e., the amount of processing) occuring at each step.

Table 2 displays correlations between scanning indices across item types and item contents, as well as within types and contents. Significant item-type (collapsed over

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Insert Table 2 about here

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content), and item-content (collapsed over type) correlations were identified for all indices.

Discussion

Identification of commonalities in performance or information processing for items varying along specific dimensions permits elucidation of particular sources of unities in reasoning. This work was designed to ascertain the extent to which knowledge stores and the presence of common performance components are important factors in reasoning. The extent of processing similarities resulting from item content and item type manipulations, respectively, reflect the relative importance of each of the two sources. Significant item-type correlations reflect that items requiring successful execution of the same performance components for their solution are processed in a similar manner whether or not items possess similar content. Significant item-content correlations indicate that common knowledge stores are important in information processing.

The results of this experiment corroborate the findings of Sternberg and Gardner (1983). Our eye movement data, reflecting processing efficiency across problem-solving stages, are consistent with Sternberg and Gardner's data on total score and performance-component latencies. Taken together, the data point to the existence of stable phenomena which are robust across a range of items differing in difficulty.

Further research is directed toward identification of unities in different types of reasoning, such as deduction. Different levels of individual differences are being examined for subjects differing along various reference-ability dimensions.

Table 1

Scanning Indices

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1. Total number of fixations (TFIX). This index is a summation of the number of individual fixations per test item.
2. Fixations prior to first distractor excursion (FIXPDX). This index is defined by the percentage of total fixations occurring prior to the first excursion to the distractor field. The index suggests the point at which a subject first breaks ongoing processing to attempt confirmatory activity.
3. Total number of distractor excursions (TDX). A distractor excursion is defined by two successive fixations, the first of which occurs on either an A_i or C location; the second fixation falls upon a point in the distractor set (i.e., a D_i). The number of distractor excursions is hypothesized to indicate the number of times a subject breaks ongoing processing in order to attempt confirmatory activity.

Table 2

Correlations of Scanning Indices as a Function of

Item Type and Item Content

	Over Type[a]	Over Content[a]	Within Type[b]		Within Content[c]	
Variable	Verbal-Figural	Analogies-Series Completions	Verbal-Figural Analogies	Verbal-Figural Series Completions	Analogies-Series Completions/Verbal	Analogies-Series Completion/Figural
TFIX	.82	.58	.70	.84	.46	.60
FIXPDX	.62	.37	.75	.27	.06	.47
TDX	.85	.62	.79	.76	.36	.67

Correlations underlined are significant at < .05; n = 37.

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